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JUNCTION OF QUARTZ WITH METAL

by L. V. Nikolayev.

- USSR -

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JUNCTION OF QUARTZ WITH METAL

-USSR-

Following is a translation of an article by L. V. Nikolayev, Scientific-Research Radiophysics Institute under the GGU, in the Russian-language periodical Pribory i Tekhnika Eksperimenta (Instruments and Experimental Techniques), No. 5, September-October 1962, pages 174-176. Received 26 October 1961.

The author demonstrates the possibility of obtaining a stressed junction of quartz with metal for manufacturing waveguide windows for ultrahigh frequency (UHF) devices. Welds of such a type are vacuum-sealed and have high thermomechanical strength.

The need for developing electrovacuum devices in the UHF range involving high capacities raises a number of problems requiring essentially a solution de novo. Specifically, such a problem is the preparation of HF coaxial and especially waveguide outputs. The leadout, consisting of a metal clamp with a dielectric fastened in it, comprises a part of the tube's casing, therefore the requirements of vacuum-tightness and heat strength are placed on this leadout.

Until recently the main dielectric materials being used for the manufacture of waveguide windows were glass, ceramics, mica and synthetic sapphire. In proportion to the rise in the output capacities of the UHF devices, there appeared the acute need for power leadouts having higher dielectric and thermomechanical properties. If we compare the properties of the various materials presented in the table, it is evident that, in the sum of its electromechanical properties, quartz is almost an ideal material for making high capacity leadouts in UHF devices. Having a working temperature of around 1500°, slight-

ly inferior in this respect only to the working temperature of sapphire and high-alumina ceramics, it surpasses them in its electrical properties. Quartz has a small tangent of loss angle and a low dielectric constant. At the same time, it has excellent heat strength, not comparable with that of other materials.

The ever-increasing interest being manifested in quartz as a material for windows serving as power leadouts also gives evidence that this is one of the best materials which will be used for this purpose. Thus in recent times, several reports have been published on the successful use of quartz in the designs of UHF devices. The authors of the reports [1 - 4] especially point out the entire difficulty in developing such junctions of quartz with metal lies in the exceedingly low linear coefficient of thermal expansion of quartz, and this prevents one from choosing any metal or alloy with the same coefficient so as to exclude the origination of stresses in the junction during the temperature effects.

All known designs of waveguide power outputs, be they made of glass or of any other material, are made on the basis of the principle of a close selection of materials according to the coefficient of thermal expansion (c.t.e.), which for practical reasons can not be done for quartz. Therefore the authors of various junctions of quartz with metal resort to all possible technological schemes in order to avoid the origination of stresses in the window material in the finished junction comprising some unit of the device. Without going into a detailed discussion of the processes transpiring during temperature effects on windows of any given type, it is worth noting that if we take a dielectric and a metal, into which it is built, with a c.t.e. differing considerably from the c.t.e. of the dielectric, then the latter, being incorporated in the metal at a high temperature, undergoes a compression force at practically any lower temperature.

This circumstance was set at the basis of making the proposed quartz windows in the form of stressed junctions of quartz and metal. The development of a window where the quartz would always be in a constantly compressed state, is possible owing to the fact that quartz

having a compressive strength of around 16,000 - 20,000 kilograms per square centimeter, is capable of sustaining tremendous loads, provided that they are distributed uniformly. In the course of the experiments on the junction of quartzitic plates into metal, we established that quartz, constituting silicon oxide in chemical composition, similarly to other oxide materials, for instance ceramics, sapphires etc can be wetted with a solder in the presence of active metals, such as titanium and zirconium. Thus, in all cases the sealing of the quartz plate in the clamp's metal was accomplished by soldering it with the aid of active metals, in a way similar to that used in the production of metal-titanium junctions or metal-ceramic junctions with the additions of active metals to the solder.

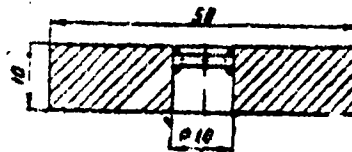


Figure 1. Schematic drawing of junction of quartz with metal (window).

Both round and rectangular windows were made. Melted quartz was used in making them. We must note that success could not be attained in joining crystalline quartz with metal; this is evidently connected with the anisotropy of the crystalline quartz's properties. The dimensions of the round windows ranged from 4 to 30 millimeters. The maximum size of a window was predetermined by the dimensions of the available quartz and evidently there is not a limit to the making of such a type of windows. The rectangular windows were made in two sizes: $3 \times 7 \text{ mm}^2$ and $10 \times 23 \text{ mm}^2$, however other variants are possible. The corners of the rectangular windows were rounded. The thickness of the quartz plates ranged from 0.2 to 2 millimeters, depending on the window's size. A coaxial type of junction was also made. The design of the windows and of the coaxial junction is shown in Figures 1 and 2 respectively.

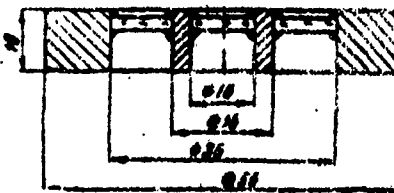


Figure 2. Schematic drawing of the junction of quartz with metal (coaxial).

The machining of the quartz, the preparation of the billets, and the cutting of plates with the required thickness and shape were accomplished on an ultrasonic lathe. The quartz plates were ground and reduced to the needed thickness in an iron chuck with the use of abrasive powders. After processing, the quartz plates should be free of scratches and cracks. The plates' surface contacting the clamp was left dull so as to assure the best wetting with the solder. The remaining surface of the plates can be polished. In one case titanium and in another, kovar (fernico) was used as the metal for the clamp where the quartz was attached. As was indicated above, in both cases the quartz plate was joined with a metal solder with the aid of an active metal, namely titanium. Other than degreasing, no other preparation of the metals' surface prior to soldering is needed. In the first case, we used as a reactive metal the clamp itself, and in the second case, titanium in the form of a hydride was added to the solder (a copper-silver eutectic ECP-72, amounting to 8 - 10% of the weight proportions). As was established, the quality of the junction and its reliability depend on the clearance between the clamp and the quartz plate. Before the soldering, it should correspond to a sliding fit with reference to techniques requiring the second class of precision. A strict proportioning of the solder is needed. The amount of solder is determined by trial-and-error and depends on the size of window and the thickness of the plate being soldered-in. Before soldering, we carefully degreased the parts in gas and then in alcohol. The brazing was done in a vacuum furnace at 800°C and with a vacuum of at least $2 \cdot 10^{-5}$ mm merc col. The junction was set horizontally in the

Physical-Mechanical Properties of Certain Insulating Materials

Characteristic	Mica Muscovite	Mica Phlogopite	Walter quartz	23-5	Pyroter- ite	Sapph- ire
Resistance to: Tear (kg/cm ²) Compression Bending	170-350 3700-5150	150 - 210 2050-2650	600 - 1200 16000-20000 600-700	300-510 6000-10000 Poor	550-800 3500-6000 1250-1600	4100 21000 4500-7000
Working tempera- ture, °C	500	900	< 1400	550	< 1350	1700
ε at frequency of 50 10 ⁹ cps tan δ at 10 ⁹	6 - 7 5.4 3 · 10 ⁻⁴	5 - 6 5.0 5 · 10 ⁻³	-- 3.5 - 3.7 3 · 10 ⁻⁴	-- 5 - 6 4 · 10 ⁻³	-- 6 - 6.5 3 · 10 ⁻⁴	-- 6.6 - 10.5 < 1
Mean coefficient α linear expansion (α · 10 ⁻⁷)	--	--	3.0	4	30	90
Heat conductivity, cal/cm · sec. °C	--	--	6.4 · 10 ⁻³	1.9 · 10 ⁻³	8 · 10 ⁻³	--

furnace; the solder, having the form of wire, was inserted as a ring. The vacuum furnace's design permitted the direct observation of the brazing process, thus making possible a visual determination of the junction's readiness.

The finished junctions were checked for vacuum seal and heat strength. First of all, the junctions were tested for vacuum seal in a ПТМ-4. We then checked for vacuum tightness with a glass cylinder pumped to a high vacuum (a quartz window had been built into this cylinder through a kovar junction). In turn, the glass cylinder was connected with a pressure tube. This device was evacuated and pumped out at a vacuum station. The vacuum developed in the cylinder after its processing and disconnection from the station amounted to $3 \cdot 10^{-7}$ mm of merc. col. After two months had elapsed, no change was noted in the pressure inside the cylinder. In testing for thermal shock, the junctions were heated in a muffle furnace to 600°C and dropped into water. No leaks were detected even after 15 - 20 such treatments. In an electronic device, during passage of high frequency energy current through the window, its firing due to losses in the quartz is possible. This was simulated by a test in which a quartz window, soldered into metal, was heated by a pointed flame from a gas burner to $600 - 700^{\circ}\text{C}$ and then dropped into water. After such rigorous tests, the junctions still kept their vacuum tightness.

The successful production of a vacuum-tight junction of quartz with metal, having high thermomechanical properties, furnishes a basis for hoping that similar quartz windows will find extensive use both in the manufacture of ultrahigh frequency instruments as well as in other cases.

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